NUMERICAL SIMULATION OF THE HOT SPOT GROWTH RATE IN DETONATION WITH ACCOUNT FOR THE ENERGY TRANSFURE TURBULENT MECHANISM

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Abstracts
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The concept of hot spots (HS) and the hot-spot mechanism of detonation initiation are the basic notations of modern detonation physics.

Solid explosives (HE) are heterogeneous, as they have pores and cracks, grain boundaries and phase interfaces..

The pattern of heterogeneous HE initiation can be described conventionally as follows:

1) Formation of hot spots – the stage from the moment of HE compression by the shock wave to the onset of the chemical reaction at local points.
2) Hot spot growth – propagation of the decomposition reaction through surrounding HE.
3) Interaction and fast merge of hot spots – fast completion of the reaction at high temperature and pressure at the moment, when reacting regions start merging, which enables fast transition to the self-sustained steady-state detonation process (explosion proper).

The time of detonation induction is determined by the characteristic time of the second stage, growth of hot spots up to their contact with each other. For the characteristic size of HE grain ~100 μm and the characteristic detonation induction time ~1 μs, the hot spot growth rate should be not less than 50÷100 m/s. This is much higher than the rate of usual layer-by-layer combustion.

The paper discusses possible physical mechanisms of HS growth. A quasi-self-similar solution to the problem of HS combustion in compressed HE after shock propagation is set up. Isobaric gas-dynamics with Arrhenius law combustion is considered. The governing mechanism of energy transfer is turbulence, which occurs due to the multi-dimensional character of combustion and HS growth and as a result of gas-dynamic shear instability at the combustion front. Because of the high intensity of turbulent mixing, such flows facilitate faster heat transfer and propagation of chemical reactions, including combustion.

The paper presents 2D HS growth simulations using the k-ε turbulence model and 3D direct numerical simulations of instability and HS growth with turbulence and heat conduction in the EGAK-3D code. The problem is considered from the moment of HS seeding by shock-driven strong heating of compressed pore gas and its evolution. It is shown that the expected HS growth rate is provided only by the simulations which include both turbulence and heat conduction.

The simulated HS growth rate of above 100 m/s confirms the hypothesis of the turbulent mechanism of energy transfer in the course of HS growth during detonation initiation. The physical pattern is as follows: The shock wave and the vortex flow make large-size particles break up into small fragments and to mix. Energy transfer in space proceeds mainly through turbulence, and owing to the developed HE/decomposition product (DP) contact surface, HE has enough time to heat up through molecular heat conduction (energy transfer from DP), and the decomposition reaction continues effectively (combustion with heat conduction from the surface of small particles).

The results of this work substantiate the turbulent nature of the energy transfer at the phase of heterogeneous HE initiation and the heat conductance role in cold HE heating on the developed HE and DP interface at grain fragmentation and vortex flow in the reaction zone.